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Flood Analysis by Finite Elemental Method using Laser Measurement Data

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***ABSTRACT*:**
The laser measurement data and building form data are processed automatically, and the flood overflow analytic model of the city part is made. An analytic model is made the triangle mesh which can express a building plane form, and an analytic calculation adopts finite elemental method. It considers how much analytic model preparation is reduced with this technique. And, the effectiveness of an analysis and an analytical model is considered by comparing a measurement value and an analytical result of the flood of the Fukui Prefecture Asuwa river that occurred in July, 2004.

KEYWORDS: Laser measurement data, Flood analysis, Finite Elemental Method(FEM)

1 Introduction

The Japanese central government and the local government promote actively the maintenance of the hazard map and the policy for the disaster prevention measures to a large-scale disaster that is a frequent occurrence in recent years. The river hazard map that shows the flood situation and the flood scale is announced by an administrative organ service. They plan to extend the maintaining river as far as a small and medium-sized river. The policy "Urgent measures for downpour disaster action plan" is under way by the Ministry of Land Infrastructure and Transport. They think that it is necessary to form more accurate information related to the disaster as soon as possible, therefore the flood analysis will become important more and more in the future.

It is possible to consider that the flood analysis by FEM in consideration for building shape, but this method is hard to get a good result for next three reasons.

First, it is hard work to make a triangular element for the analysis from the plan (paper and drawing data).Second, it is not easy to gather the survey data. Third, it is difficult to get a stable result because the result is dependent on a triangular itself even if we can make an excellent triangular element. In the measurement world, it was put to practical use the laser scanner carried in aircraft. That is easy to get the widely altitude data. There are reported some cases that the laser measurement data combines the aerophotograph into the constructing three-dimensional city model automatically.

We thought that it was possible to get the answer to convert from laser measurement data into flood analysis model (landform and building shapes).

In this paper, we describe how to make a flood analysis model automatically from laser measurement data.

Then, not only do we compare, but also we consider the comparison between the surveyed value and analyzed value at the flood disaster of the Asuwa river in Fukui Prefecture that had occurred in July,2004.

2 Automatic attribute distinction method

2.1 mesh means and smooth analysis

First, we divide the altitude into cell, and calculate the mean coordinate each of meshes(Xa,Ya,Za).Next, we calculated the varying of altitudes every cells and examine the distribution in each cells. It was assumed that the mesh was flat if all points were within Za±0.5 this time. Fig 2 shows the plotted flat mesh sectionally, and it is classified into the surface of the ground part and the building part.

2.2 Making altitude group and boundary analysis

The building shape comes into view when the surface of the ground part is taken out in two-dimensions.(Fig.3)

We can make the building shape from picking up the borderline between the flat 0 and 1 that the mesh where data exists is assumed to be 0,and where data doesn’t exist is assumed to be 1. To reduce the number of laser measurement data by the method of the above-mentioned, the building data (dxf form) that recorded the boundary between ground and the building and 5m mesh and 10m mesh that are processed point group data.

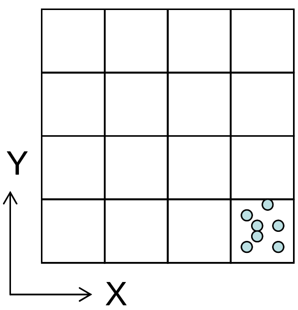


Fig.1 Point in plane lattice and cell

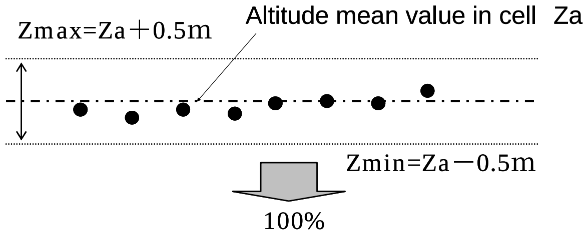


Fig.2 Cross section in a cell

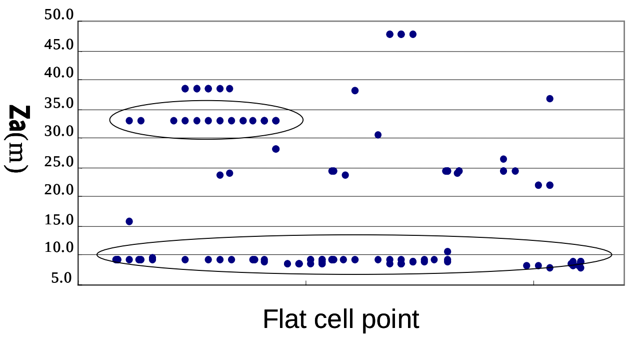


Fig.3 Cross section of flat cell point

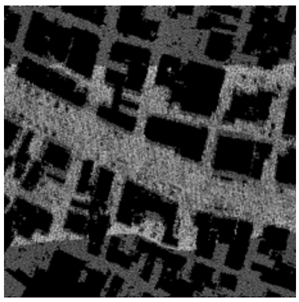


Fig.4 Flat mesh group of the ground part

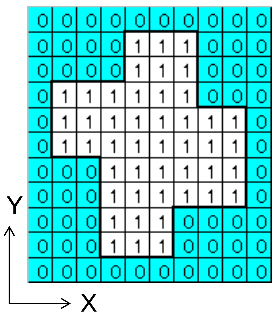


Fig.5 Borderline extraction with cell

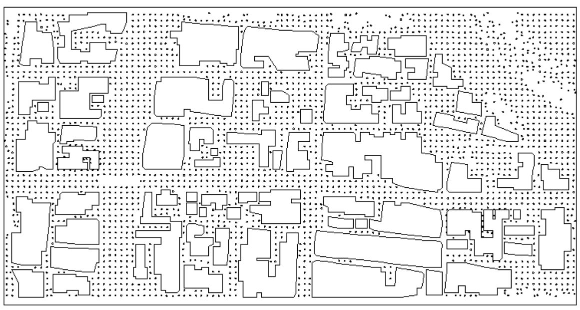


Fig.6 point data and building data

3 The model for analysis

We make a triangular element from the processed point group data and the building data in order to analyze the flood by the FEM. We developed the program to prepare for the making a triangular element that reprocess the point group data and set the building height. We attempted to shorten the making time of an analytical model of triangular elements by using LandDesktop3 of software on the market (Autodesk Co. and henceforth LDT3).

3.1 Reprocess the point group data

In general, FEM is said that the more sides of element are equal like as a square and an equilateral triangle, the more the result of calculation excels at both stability and accuracy. Also it is said when the element that a flat rate is extremely high (It is long and slender) exists, the instability of the analysis and the deterioration of accuracy are caused. Therefore, so as not to make a long and slender element, the processing of a)-c) was given.

a) Delete the minute distance point of building

When the minute distance point exists which is shown in Fig.7, a long and slender triangle is made. In this case, the even triangle is able to make by deleting a minute point below the set value .The set value went by 10% at mesh widths.

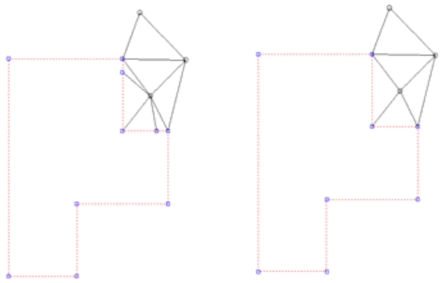
b) Add points to building line

When the composition point interval of the building is long, a long and slender triangle is made. (Fig.8) In this case, the triangle with even sides is made by adding the point of equal intervals on the building shape.

The calculation method how to add points on the triangle side is next. First, we decide the distance D which is standard parting length. D is had to set less than 150% or mesh width. Second, we divide by D and the quotient which is rounded up become the parting number. Then, we divide the side by this parting number.

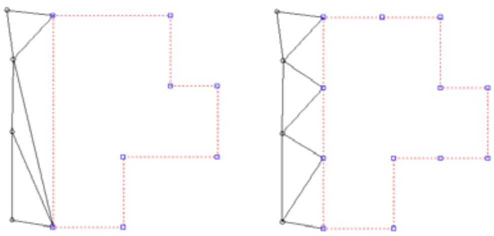
c) Delete points to building line

When the point data exist near the building, shown in Fig.9, a long and slender triangle is made. In this case, we get the homogeneous triangle after offsetting outside the building shape and deleting points among the triangle. The offset value went by 50% at mesh width.



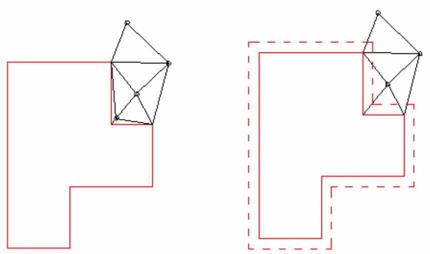
Before After

Fig7 Delete the minute distance point of building



Before After

Fig.8 Add points to building line



Before After

Fig.9 Delete points from building line

3.2 Height setting of building shape

The building shape point is in some respects on the line of the building shape. We cannot get direct the building shape point from the laser measurement data which we need for flood analysis. We can get the point of rooftop or roof from the laser measurement data, but we need the altitude around ground level which is between ground level and others. Therefore, we have to set the height to use for making a triangular element. Fig.10 shows the method of setting altitude for example. Point A, B, C, and D are reprocessed point group data and we will calculate the altitude at the point X. Point A, B, and C are almost same altitude as ground level, and point D is on the rooftop that is high altitude. For the reason, point D is influence for the result of this calculation, and so the altitude of point X become higher than the ground level. Therefore, we calculated after deleting the processed point group data which is inside of building shape. If the point didn't exist in the line of building shape, we would be able to judge the altitude of calculated point was almost ground level, because the point X was calculated from the triangle ABC. LDT3 has the function of this calculating TIN model(Triangle Information Network) that is the calculation for the altitude at the point X, and this function contributed the shorten the work time of giving altitude for building shape point.

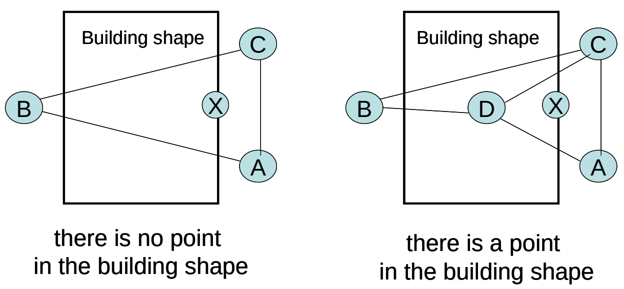


Fig.10 Height setting of building shape

3.3 Create triangular element automatically

After the mentioned process , we create a triangular element automatically with the function TIN model, LDT3.

① extract the point group data and coordinates which are defined the altitude of building shape point

② delete the triangular element which is made in building shape and whose side is the boundary line between a building and ground level

③ create triangular element automatically

④ output the TIN information to the LandXML form and convert to nodes and elements for flood analysis

4 Flood analysis

This time, the flood of the Fukui Prefecture Asuwa river on July, 2004 was assumed to be a case study, and we compared the simulation value of flood analysis and the measurement value. Fig.11 shows the analytical object area where is 500m in width ×260m in length including the overflowing point.

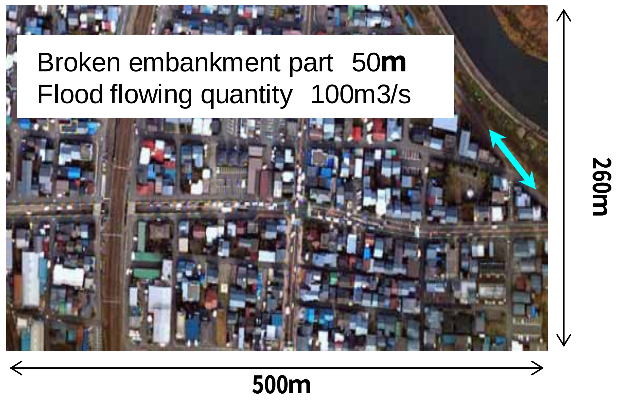


Fig.11 Analytical area

An analytical model was made by the method of the description in the preceding chapter. We make two kinds (the mesh interval is 5m and 10m) of processed point group data, and compare how much save time to make models and accuracy of flood analysis.

Moreover, Fig.12 shows the analytical model of 10m. The road passing under a railway where the altitude is low is designated on Fig.12 as a round part. We cannot get altitudes form the laser measurement data like as this case, so that we gave altitude manually to this road. The appearance from which the under passing part is corrected not the altitude of the railway but above sea level of the road where water actually flows is understood. The purpose of this paper is to consider hoe useful to make an analytical data is, so that we omit a detailed explanation of the flood analysis technique. We referred to the document for a basic equation, the finite element method, and the flood analysis technique used for the flood analysis.

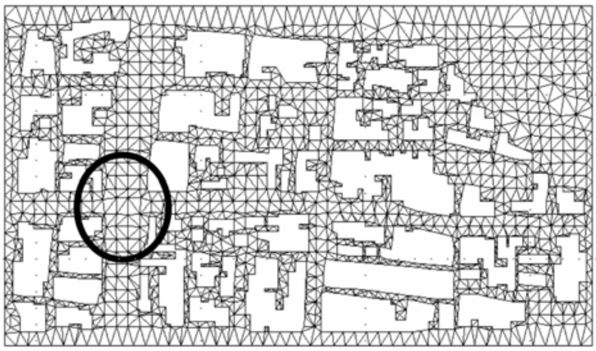


Fig.12 Analytical model

5 Consideration

5.1 making of analytical model

Table-1 shows the model making time that contain the hand correction time. 【】 inside is the time to correct manual the round part of Fig.12. We described the number of nodes and elements for the reference. It took 50 hours the case making analytical model without an automatic program. The model making time ended in 14 hours including 6 hours of 10m model making time and 8 hours of the preprocessing program making time for triangular elements. In a word, the required work for making model of 50 hours became 6+8=14 hours, and working hours was able to be suppressed to about 1/3. This time, 10m model's case, we decided by trial and error the minute points of deletion and the addition points on the line of building shape. However, 5m models' making was set values easily, and making model time further shorter than 10m model.

Table-1

Model	Making time (hour)	nodes	elements
5m	3. 0【1. 0】	4484	7014
10m	6. 0【1. 0】	2316	3227

5.2 the result of flood analysis

a)Flood simulation

Fig.13 shows the flow velocity vector chart of every two minutes right after overflowing. We confirmed the process of overflowing by executing the limited element analysis that considered the building shape. Whether the phenomenon was able to reproduce by the analysis becomes the important point because the flood exceeded the railway and it had reached the west side in an actual phenomenon. In the result of analysis, it was able to show that big flow velocity generated immediately after overflowing, and flew into the road that ran from east to west at the center of an analytical area, in a word, we confirmed the westering flow. Moreover, it was also reproduced that would reach the railway in six minutes after overflowing, and the phenomenon that flowed to the west side through the under passing part afterwards.

b)Comparison with measurement value

This time, we inspected the useful of making model, so we compared the calculation value and the measurement value that had been obtained from the flood analysis about four points in an analytical area. The measurement value here is the altitude that the flood that assistant professor Hirofumi's Yamamoto of the Fukui University the education and the region science department laboratory member requested above sea level of a near road etc. based on the flood signs right after the disaster reaches. When comparing it with the calculation value, it is assumed that this altitude is treated as a water level of the flood at this disaster. Fig.14 shows the water level of the flood every two minutes right after overflowing. Fig.15 shows the comparison points, and Table-2 shows the comparison between the measurement value and the calculation value (water level of the flood after ten minutes). Four round points shown by Fig.13 were compared with the calculation value. As for both 10m models and 5m models, a small error and, excellent result were obtained. For especially 5m model, the error is 5% or less. Moreover, the case compared with 10m model and 5m model, the calculation result of 5m model became near the result of measurement value. It is intended that the factor is the accuracy of the model because 5m model is more detailed than 10m model. In addition, it is thought that the more detailed model is made, the more accuracy improves.

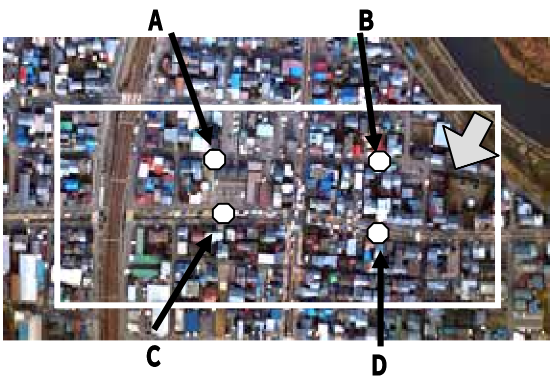


Fig.15 Observation points

Table-2

Observation point	Measurement value (m)	Calculation value(m)		Error margin rate(%)	
		5m Model	10m Model	5m Model	10m Model
A	8. 6	8. 7	8. 3	1. 16	-3. 4
B	9. 8	10. 1	10. 1	3. 06	3. 0
C	9. 5	9. 7	9. 6	2. 11	1. 0
D	8. 6	8. 2	8. 0	-4. 65	-6. 9

6 Conclusion

In this paper, a great saving for analytical model making was able to be confirmed by processing the laser measurement data automatically. It seems that there are a lot of artificial structures of the city part in the building etc. , and shape is complicated more and more. Moreover, the laser measurement data is effectively used for three dimension space change because of the new construction etc., and the accuracy model making becomes important technology. We want to work on the mountains part model making other than the city part in the future. The problem of the model making is when the structure like as the overpass etc. overlapped by the laser scan to get, the structure with a high altitude. This time, it went manual to correct altitudes in the railway part. The function for the self adjustment of that part will be needed in the future. Moreover, we learned that the automatic retrieval and correction for the flat element and accuracy improvement of the linearization of the building shape. We plan to develop those functions in the future. This time, the function of LDT3 that was three dimensions CAD software was used in the program development. It has evolved to the one that the notebook computer is enough to operate recently though three dimensions CAD were operated only by a super-high spec such as large-scale general purpose machines and workstations 20 years ago. However, the current state cannot finish to spread on the business because the engineer cannot master the three dimensions CAD well yet, and being spread three dimensions CAD in the future becomes one of the problems. The function of CAD is understood that it is sufficient to use for the numerical analysis model making though a lot of three dimensions CAD have been originally used by designing and constructing roads and creations, etc. The result in which the result of flood analysis was excellent was able to be confirmed.

Because of the problem of a hard spec, natural phenomenon is three dimensions, but an analytical simulation is replaced from two converted dimensions that cannot be accurately solved the problem. There are a lot of natural disasters all over the world, and it will continue, and exceeded scale has been assumed to occur in the future in recent years. Therefore, it seems that the field of an environmental forecast, disaster prevention, and the crisis-management is paid to attention, and the role that the information technology and the calculation mechanics become larger in order to answer. We think the laser measurement technique will put in practical use in wide fields other than the flood analysis in the future.

References

G.Okada et al.: Flood analysis in city region by finite element method, *Civil Engineering association 59th annual science lecture meeting, pp.53-54, September 2004*

H.Masaharu: Airlines laser scanner, *P21,Zensokuren 2001 new year era*

Kawahara, Umetsu:Two Step Explicit Finite Element Method for Sediment Transport,*3rd Sympo. River Sedimentation, Jacson USA, pp1487-1495, 1986.*

K.Kawamoto et al.: Research for river and road model making technique with laser scanner, *Civil Engineering association 57 annual science lecture meeting, pp.393-394, September 2002*

K.Ota et al.: The city model's automatic construction with fusion, *annual science lecture meeting of Japan Society of Photogrammetry Remote Sensing, pp.135-138,June 2003*

K.Takeya: automatic element division method, *the 22th Kanto branch technology research symposium lecture outline collection, pp.124-125, March 1995*

K.Tate: flood analysis depends on non-structural lattice model, *Civil Engineering association 58th annual science lecture meeting, pp.133-134, September 2003*

K.Yamamoto et al.: About effective use of the laser measurement data by the automatic attribute distinction method, *The 30th information technology used symposium thesis* .

Matsumot, Umetsu: Examination of positive finite element method analysis with bubble function, *the 8th Japan Society of fluid mechanics symposium, pp635-638,1994.*

M.Ueno et al.: Flood analysis by finite element method with laser measurement data, *The 30th information technology used symposium thesis*

T,Taniguchi: element automatic division for FEM, *Morikita Shuppan Co, September 1992*

Umetsu:A Boundary Condition of Moving Boundary Simulation for Broken DamProblem by Three-Step Explicit Finete Element Method, *Advances in Hydro-Science and Engineering, Vol II , China, pp394-399, 1995.*

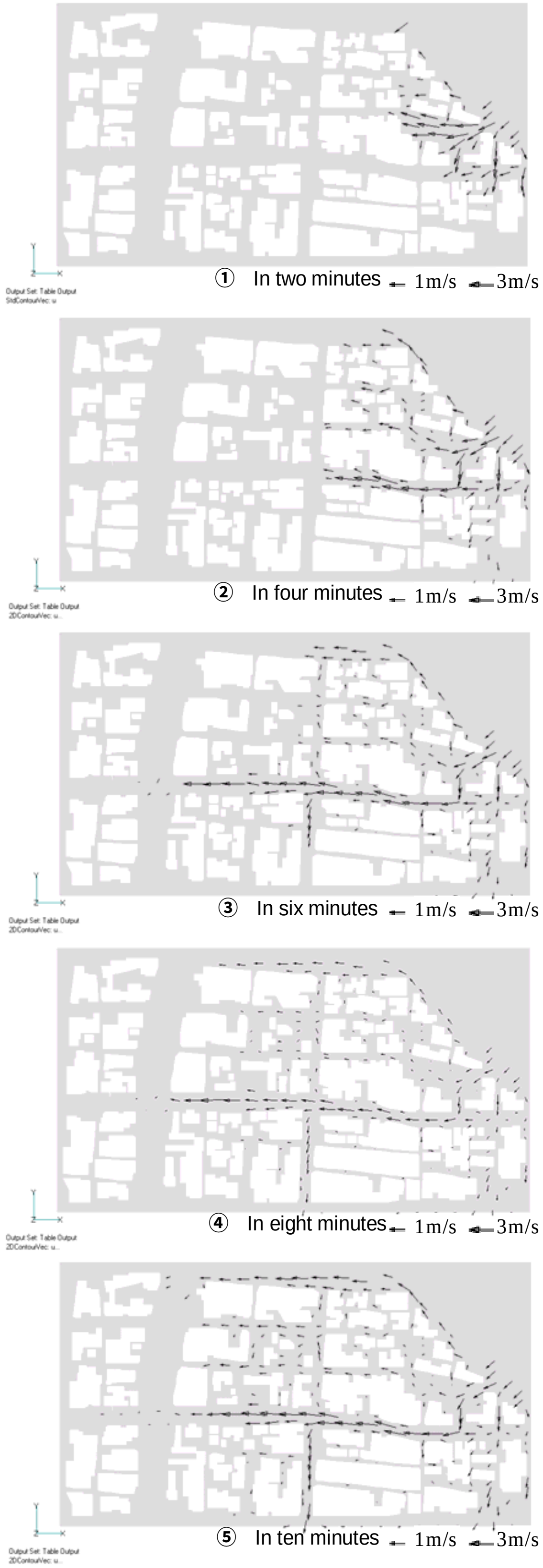


Fig.13 Flow velocity vector chart

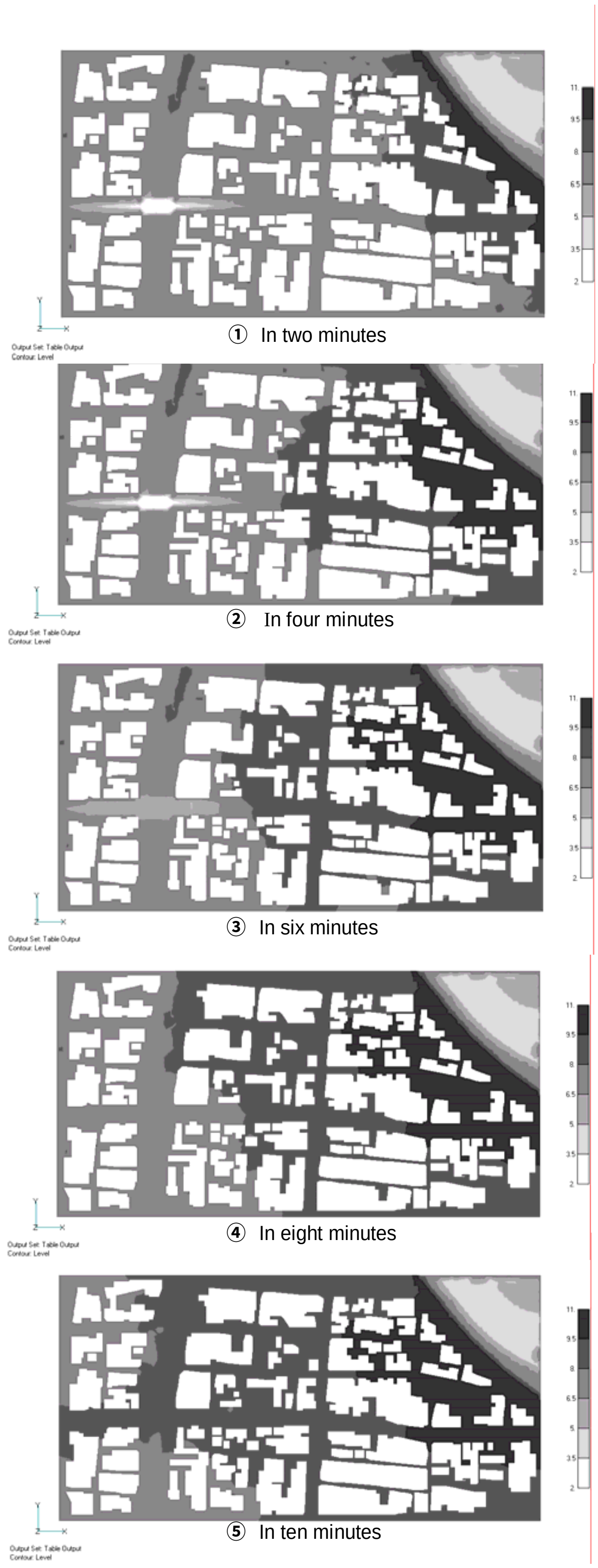


Fig.14 Water level of flood chart